Cast Polycrystalline Silicon PV Modules

Highlights

- Doubled capacity for producing cast polycrystalline-silicon
- Tripled production volume
- Dropped the cost to manufacture a framed power module by 20%
- Reduced by 40% the cost to manufacture lowest-cost module

Solarex participated in the 1993 solicitation of PVMaT—a cost-shared partnership between the U.S. Department of Energy and the nation's PV industry to improve the worldwide competitiveness of U.S. commercial PV manufacturing.

PVMaT Fact Sheet
Photovoltaic Manufacturing Technology

Solarex

Goal

The goal of Solarex under the 1993 solicitation of PVMaT was to advance PV manufacturing technologies, with general objectives to:

- improve cast polycrystalline-silicon PV manufacturing technology
- cut module production costs by half
- increase module performance
- expand commercial production capacity by a factor of three.

Background

For nearly 20 years, Solarex has made PV modules with polycrystalline silicon cells that comprise many large grains of silicon. Today, polycrystalline silicon modules hold 37% of the world's PV power market and are a favored option for PV power because they are reliable, long lasting, and efficient.

This polycrystalline module technology is relatively mature; yet, there is room for improvement.So, under this PVMaT project, Solarex investigated its entire process—from casting ingots to assembling modules—to find ways in which to reduce manufacturing costs while improving module performance.

Technical Approach

The process begins with ingot casting, to produce the polycrystalline-silicon wafers with which modules are made. Solarex uses its patented directional solidification process, in which silicon feedstock is melted in a ceramic crucible and solidified into a large-grained semicrystalline silicon ingot. The ingot is then cut into bricks, which are sliced into wafers.

The wafers are made into solar cells by screen-printing silver paste onto the front of the wafer to form the grid that carries the current. This is followed by high-temperature processes—including firing of the front print paste, diffusion of the phosphorous dopant to produce the PV effect, and chemical vapor deposition of the antireflection coating—all done in belt furnaces with automatic loading and unloading.

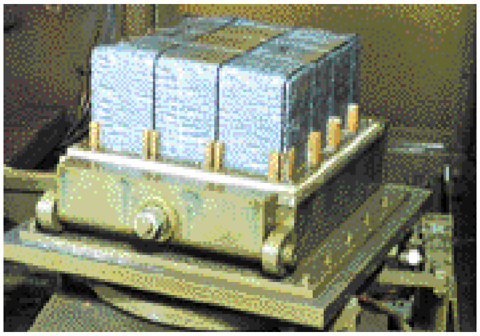
Next, the automated assembly system tabs cells, lays them up, and solders them into a matrix of 36 or 72 cells. This matrixes laminated into a package with a low-iron, tempered-glass superstrate, ethylene vinyl acetate encapsulant, and Tedlar backskin.

Results

Solarex identified several areas to improve its process: casting larger ingots, using wire saws to cut wafers, automating wafer handling, incorporating a back-surface field in its cells, automating module assembly, and designing a frameless module.

Larger Ingots

For its products—based on square cells that measure 11.4 cm (4.5 in.) on a side—Solarex has traditionally cast ingots that could be sawed into four bricks, each 11.4 cm on a side. Under this PVMaT project, Solarex developed a method to cast massive ingots—ones large enough to produce nine such bricks.



BP Solarex/PIX04571

By casting larger ingots of silicon, Solarex doubled its production capacity. Here, the larger ingots are sawed into nine bricks that are processed into wafers.

The new process may also be used to make ingots that can be cut into bricks of different sizes. One option results in bricks that may be sliced to produce 11.4-cm x 15.2-cm (6 in.) cells. Another option produces four bricks, each 15.2 cm on a side.

For its new casting ability, Solarex chose to modify its existing casting stations rather than to buy new stations. As a result, Solarex doubled its casting capacity, for 20% of what it might otherwise have cost.

Wire Saws for Cutting Wafers

Under this project, Solarex replaced many of its internal diameter (ID) saws with wire saws, which may be used to cut a variety of wafer sizes. They can also cut thinner wafers—on centers from 500 down to 400 micrometers. They yield at least 20% more wafers from each ingot than do ID saws, increasing the watts produced per kilogram of silicon purchased. And each wire saw produces as many wafers as up to 24 ID saws, with higher yields and lower per-wafer cost. Today, Solarex relies on wire saws to cut most of its wafers.

BP Solarex/PIX08178

PV cell automatic print line.

Automated Wafer Handling

One barrier to achieving high yield is wafer breakage, especially with thin wafers. To overcome this problem, Solarex subcontracted Automation and Robotics Research Institute (ARRI) to develop a system that could automatically handle wafers and cells that were 200 micrometers thick and 15 cm on a side. Among the design constraints were that the system had to have a breakage rate of less than 0.1% per handling step and a throughput of at least 12 cells or wafers per minute.

ARRI developed a model to simulate a typical wafer-handling situation, estimate the maximum load that can be applied during handling, and calculate the corresponding probability of failure. This work led to the design of a flexible system for picking up and moving wafers and cells.

Cell Back-surface Field

Solarex wanted to increase cell efficiencies to 15%, while decreasing the cost per watt at the module level. After investigating several process modifications, the company incorporated a back-surface field (BSF) in its cells. A BSF increases cell efficiency by repelling charge carriers back to the junction for separation and collection. Solarex easily implemented the BSF by using its own low-cost process for thick-film paste metallization.

After showing that an aluminum-paste BSF can increase cell efficiency by about 5%, Solarex transferred the process to manufacturing for use on a significant percentage of its cells. The process, which continues to be optimized, has thus far boosted cell efficiencies by 4.5%.

Solarex has a fully automated BSF screen-printing system at its Frederick facility (Maryland) that includes three automatic screen printers—one each for printing back pads, aluminum paste, and front silver grid patterns.

Automated Module Assembly

Toward its goal of doubling throughput while halving labor, Solarex subcontracted ARRI to detail the module-assembly steps, model the manufacturing process, and recommend improvements. When implemented, these changes increased production capacity by 40%.

ARRI also developed a new factory concept that enables incremental increases to meet shorter-term capacity requirements, and Solarex implemented this concept, which could triple module-assembly capacity.

Frameless Modules

One of the goals was to develop a frameless module design using a low-cost (<\$0.50/m^2) backskin material and a user-friendly, low-cost (<\$1.00/module) electrical termination. Solarex chose Tedlar as the backskin and pigtail (or twisted) wires with crimp connectors and shrinkable tubing insulation for termination. Solarex designed modules to mount directly onto the support structure without integral frames. After trial and error for direct mounting methods, the company settled on RTV, which has been used successfully on several systems.

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Company Profile

Founded in 1973, Solarex, now called BP Solarex, was one of the first commercial companies specializing in terrestrial photovoltaics. In 1979, Solarex developed its semicrystalline ingot casting process and became the first company to commercialize polycrystalline cells.

In 1983, Solarex purchased RCA amorphous silicon.That same year, Amoco Corporation, which had been investing in Solarex since the late 1970s, consolidated its holdings to become the sole owner. Solarex became part of Amoco/ Enron Solar in 1995 when Amoco and Enron joined in a 50:50 partnership to expand the base business of Solarex, build an amorphous silicon manufacturing facility, and develop solar-power electric generation facilities.

In late 1997, Solarex began operation at its new 10-MW amorphous silicon plant, becoming the first company to successfully commercialize two PV technologies.

Solarex is involved in all commercial aspects of PV, including the manufacture, sales, market development, application development, systems development, reliability testing, process and equipment development (particularly automation), and research and development of new processes, materials, and products.

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